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Memorandum

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Date: November 17, 2008

Subject: MT 234-1(16)21; Taylor Hill Road; CN 6382
Geotechnical Engineering Alignment Report (464)

The Geotechnical Section has completed the analyses for alignment of the subject project.

1.0: INTRODUCTION

1.1: Intent. The purpose of the proposed project is to reconstruct the existing 24-foot wide two-lane aggregate surface road to generally meet current standards for major secondary roadways. The proposed alignment will result in safety improvements through modifications to the existing vertical and horizontal alignments.

1.2: Location. The project is located in Hill County approximately 20 miles south of Havre and immediately east of the Rocky Boy Reservation boundary on Secondary Highway 234 (S-234), also known as Taylor (Hill) Road. The proposed project alignment begins near the Rocky Boy Reservation boundary and extends easterly approximately 2.3 miles, ending at the Hill County Property/Beaver Creek County Park line. The proposed alignment generally follows the existing PTW, but removes or reduces several vertical and horizontal curves. It is important to note that while stationing increases from west to east, reference posts increase from east to west.

1.3: Geology/Soil Conditions. Volcanic rocks predominate the complex geology of the project area. Major rock units include mafic extrusive flows, flow breccias and pyroclastics with minor amounts of thin, locally-derived interflow sedimentary layers. Geologic maps indicate the entire proposed alignment will traverse volcanic rocks of Tertiary age.

Soil thicknesses will vary with the topography along the alignment. Local highlands generally coincide with bedrock outcrops and minimal soil cover. Soil depths within intermediate areas and wetlands will be more substantial. Wetlands and minor drainages may be filled with considerable thicknesses of soft, organic soils.

2.0: FIELD INVESTIGATION

2.1: Drilling and In-Situ Testing. Drilling was conducted with the CME 1050 and CME 850 drill rigs, each using 8 inch hollow-stem augers and NQ core barrels. Standard penetration tests (SPT) were conducted at regular intervals. Soil and rock samples were collected for lab analyses. A total of 30 borings, ranging in depth from 12 to 58.8 feet, were drilled in July, 2008 to evaluate the proposed alignment. All borings were completed prior to a plan revision involving an alignment shift between approximate station 197+00 and 214+00. As such, borings #4, 5, 33, 34 and 35 are located significant distances from the proposed centerline. Access difficulties sometimes restricted centerline proximity for other borings.

2.2: Laboratory Testing. Soil samples collected during the field investigation were analyzed in the lab for classification and in-situ moisture content. Rock cores were subjected to unconfined compressive strength testing. Summary sheets of the laboratory results for the soil and rock samples are attached.

2.3: Subsurface Soils and Rock. The soils encountered during drilling were very soft to stiff clays and silts, and loose to very dense clayey or silty sands. The soils often contained fragments of native rocks, and many horizons appeared to have been produced from in-place weathering of bedrock. Silty sands, and silty sands with gravel were encountered in some of the borings near the eastern end of the project.

Approximately one-half of the borings encountered bedrock. The depth of the soil-bedrock contact was variable, ranging from 0 to 21 feet below the ground surface. The predominant rock type encountered was a dark-colored, fine to coarse-grained igneous rock (likely phonolite or skonkinite), although breccias and occasional light-colored igneous rocks were also recovered. There were no obvious bedding or jointing patterns. Bedrock hardness, observed Rock Quality Designations (RQD), and the degree of weathering varied with location.

2.4: Groundwater. Groundwater levels observed at the time of the investigation ranged in depth from 1.5 to 22 feet below ground surface. These levels will fluctuate with seasonal conditions. Groundwater was encountered at 9 of the 30 boring locations, generally coinciding with wetlands, surface springs, or small drainage areas. Subsurface soils above the groundwater table were generally dry to moist.

Boring logs are attached for reference and will provide additional subsurface information.

2.5: Additional Testing. Four seismic refraction traverses were conducted to evaluate the nature of the bedrock surface and to estimate whether ripping is a feasible option within the bedrock cuts. Seismic refraction involves the introduction of energy into the ground, the propagation of that energy to some depth, and the return of a portion of the original energy to the surface by refraction (or reflection) along surfaces of differing density. The travel time of the returning energy is recorded and later analyzed to estimate bedrock contact surface depths and the rock's intrinsic seismic velocity. The seismic velocity of assorted bedrock types has been correlated with the potential ripping capabilities of various sizes of construction equipment, and a comparison of the field results gives an indication of whether or not the rock is rippable.

The results of the seismic traverses suggest an irregular bedrock contact surface. Defining the bedrock surface is somewhat difficult as an evaluation of collected samples revealed that, in many areas, there is a gradual transition from soil to rock. Such conditions are typical of settings where the bedrock has weathered in place to create a significant soil horizon. Similarly, since the bedrock was originally deposited as individual flows separated by enough time for weathering to occur, inconsistencies in material properties are likely, especially at or near individual flow interfaces. In general, velocities increased with depth. This trend is consistent with observations of increasing rock hardness, RQD, and decreasing weathering with depth.

3.0: DISCUSSION AND RECOMMENDATIONS

3.1: Embankment Construction – General. Depending on the method of excavation employed, material obtained from cuts may contain rocks and boulders of substantial size. If materials excavated from cuts are to be used for embankment fill or embankment foundation treatment, crushing may be required to ensure that construction can occur in accordance with standard specifications.

Fills to be constructed partially over the existing roadway and partially over undisturbed lowlands will be underlain by soils of differing properties, and differential settlement is probable. The potential for differential settlement is greatest in areas where proposed fill heights are large and material soil properties differ the most. See cross-section stations 229+50, 255+00, and 301+50 for examples where differential settlement could cause future difficulties.

In order to minimize the potential detrimental effects of differential settlement on long-term performance, it is recommended that embankments be allowed to settle as long as practical prior to paving. Ideally, embankments should be constructed near the end of the construction season allowing a minimum of 6 months prior to the construction of the surfacing section.

3.2: Cut Construction – General. Geotechnical staff were informed that blasting was not required for rock cuts on the adjacent S-234 reconstruction to the west of this project.

Although we anticipate that most of the cuts on this project will similarly be rippable, it is possible that some areas will require blasting to complete excavations to design depths. Unconfined compressive strength test results conducted on rock core samples ranged from 18 tons per square foot (TSF) to 383 TSF. While no direct comparison between compressive strengths and rippability is available, those horizons that exhibit higher compressive strength values will likely be the most difficult to excavate. Comparison of the seismic velocity results with equipment capability charts suggests that, at least in some areas, the bedrock falls within the "marginally rippable" columns of the largest equipment rated. The contractor must be aware that blasting may be required to complete this project as planned. A draft controlled blasting Special Provision is attached for review. This special provision may require revisions to be project specific. We will provide a final version to include in the contract after the Plan in Hand review.

Cut slopes of ¼H:1V, as proposed in some areas, are not recommended on this project due to the inconsistent nature of bedrock weathering and competence. Instead, we recommend cut slopes no steeper than 1H:1V. 1H:1V and flatter slopes will be easier to construct with conventional equipment, and may reduce or eliminate the need for benches in many areas. If constructed without benches, the amount of additional right of way required for the shallower, more stable slopes is minimized. Even if constructed at 1H:1V, some periodic maintenance will likely be necessary to remove sloughing from benches and ditches. It should be noted that at those locations where the existing cross sections indicate 1.5H:1V slopes, we do not recommend steepening these slopes to 1H:1V. Also, consideration should be given to the need for erosion control for all 2H:1V and steeper cuts constructed within the softer soil horizons.

At those locations where a 1H:1V cut slope might be used, we have evaluated the catchment geometries necessary to reduce the rock fall debris entering the roadway. In a study sponsored by the Federal Highway Administration, the Oregon Department of Transportation established catchment area design charts for rock fall retention. The retention percentage specifies the portion of rock fall that can be expected to come to rest within the catchment area for a given slope/catchment configuration. These design charts suggests that a 20 feet wide, 6H:1V inslope will retain approximately 85% of rocks falling from a 40 feet high, 1H:1V cut slope. We anticipate higher actual retention percentages for most of this project because the majority of proposed cuts a are less than 40 feet in height. Rock fall retention can be increased by either steepening the inslopes to 4H:1V with the same 20 foot width or flattening the proposed cut slope to 1.5H:1V.

Numerous springs daylight on the hillsides and in the valleys throughout the project corridor. The contractor should be aware that some of the proposed cuts may intersect groundwater seeps. The exact location of these springs is difficult to identify due to the vegetation present and may not become evident until construction. If encountered, seepage volumes will vary with location, precipitation events, and general season. Some of the seeps may be large enough to impact construction activities, and the contractor must be prepared to deal with this possibility. If necessary, geotechnical staff will be available to provide drainage recommendations for such occurrences.

3.3: Typical Sections – General. As shown in plans, the proposed pavement section is to be constructed with only 8 inches of aggregate base course. Lab analyses results indicate the existence of A-7-6 soils in some areas, and R-values as low as 20. A reevaluation of these data to determine the suitability of the proposed base course thickness may be beneficial. A summary of the district soil survey data is attached for review.

3.4: Beginning of Project to Station 205+00 (see logs 1, 2, 3, 4, 33 & 34). Subgrade soils consists of loose to very dense sands (A-2-4), and soft to stiff clays (A-6). Bedrock was encountered in borings #2, 3, and 34 at depths ranging from 9 to 18 feet, and intermediate material (highly weathered rock) was present in all except boring 33. Subgrade materials within this section should provide adequate foundation support for the proposed embankments and associated construction activities.

The proposed alignment requires cutting into the slope to the left of centerline and filling atop the existing grade and ditch to the right of centerline. The profile indicates a maximum cut depth of approximately 10 feet, and a maximum fill height of approximately 8 feet. Based upon SPT results and observed water depths, settlement is not expected to be a significant factor. Proposed cut slopes of 2H:1V or flatter are expected to stable, and proposed embankment slopes of 4H:1V or less are expected to be stable. Major construction and long-term maintenance difficulties are not anticipated within this section of the project.

3.5: Station 205+00 to 208+00 (see logs 5 & 35). Subsurface material within this section consists of several feet of sandy clay and silt overlying volcanic breccia. As in most areas observed during the field investigation, the nature of the interface between soil and competent or semi-competent rock is a gradual, non-distinct transition. The bedrock encountered in boring 35, nearest the newer proposed alignment, is hard, but exhibits numerous fractures with relatively close spacing.

The cross-sections indicate proposed 1.5H:1V of flatter cuts on both sides of centerline with a maximum cut depth of approximately 20 feet. It is our opinion that most of material to be cut should be excavatable with modern equipment. This opinion is based upon the highly fractured nature of the bedrock encountered and the depth before competent rock was reached in boring #35. However, it should be noted that boring #35 was drilled approximately 150 feet away from centerline. Centerline conditions may vary from what was observed, and some bedrock horizons within this reach may be more resistant to ripping. Proposed cut slopes of 1.5H:1V or flatter are expected to stable, and construction and long-term maintenance difficulties are not anticipated within this section.

3.6: Station 208+00 to 227+00 (see logs 6, 7 & 8). Here, subsurface soils consist of silt, sand, and clay, and are softer within the upper 5 to 10 feet than soils near the beginning of the project. Soil depths increase as stationing increases within this section, and groundwater was observed in boring #7 at an approximate depth of 7.5 feet. This water may be associated with nearby springs as borings #6 & 8 did not encounter groundwater to the depths investigated.

Approximate maximum fill heights of 10 feet as proposed near station 213+50 are estimated to cause up to 6 inches of settlement. However, this settlement should occur rapidly during construction, and should not create significant long-term issues. The cuts within this section will likely encounter soil and/or highly weathered bedrock to the depths proposed, and should be constructible with modern equipment. Proposed slope angles are expected to be stable.

3.7: Station 227+00 to 231+00 (see log 9). Here, an alignment shift to the south in order to reduce the horizontal radius of the existing curve is proposed. This shift will encroach upon an area with loose, clayey sands and silty soils, and a high water table. SPT data suggest that these poor soil conditions extend to a depth of at least 15 feet. The observed water table elevation was near the ground surface at the time of drilling.

Maximum proposed fill heights of approximately 8 feet could result in approximately 8 inches of settlement within this area. The majority of this settlement is expected to occur during construction. However, some long-term and/or differential settlement is possible here if significant organic soils exist – though none were encountered in the boring. Based upon a comparison of similar, nearby soil types, it is likely that these soils are moisture sensitive. The combination of loose soils, high water table, potential differential settlement, and the possible existence of moisture sensitive soils may cause construction and long-term performance issues. In order to minimize negative potential effects and facilitate construction within this section, embankment foundation treatment, as described for stations 255+50 to 258+90 in the project plans, is recommended.

3.8: Station 231+00 to 254+50 (see logs10 through 16). Within this section, all borings except #11 and 16 encountered bedrock. Silty sands and sandy clays ranging in depth from 1 to 15 feet, overlie an irregular bedrock surface. Subgrade soils here are firmer and should provide adequate foundation support for proposed embankments of up to 7 feet. Resulting settlement should be limited and occur during construction.

The condition of the bedrock encountered here is variable. The rock is often fractured, fresh to highly-weathered, sometimes hard and competent, and other times very soft and friable. Rock quality (RQD) decreased with depth in all bedrock borings except #15. There is no discernable trend in rock hardness, fracturing, or the degree of weathering. The profile indicates cuts on both sides of centerline with a maximum depth of approximately 25 feet.

For long-term stability, slopes steeper that 1H:1V are not recommended due to the inconsistent nature of weathering and bedrock competence. Even at 1H:1V, sloughing is probable and periodic maintenance will likely be necessary.

Based on an evaluation of the overall RQD, degree of weathering and fractures, and observed seismic velocities, it is our opinion that most of material to be cut within this section should be excavatable using large equipment. Blasting may be required for the more competent bedrock horizons.

3.9: Station 254+50 to 267+50 (see logs 18 & 19). Here, subsurface soils will vary with topography along the width of the profile. In general, firmer soils and weathered bedrock should be anticipated beneath the cut sections. In contrast, subsurface soils within the wetland areas will be loose sands (A-2) and soft lean clays (A-6). High groundwater levels should be expected within wetland areas. At the time of drilling, water levels ranged from 3 to 8 feet below ground surface in borings #18 & 19.

Compared to the previous section, cuts within this reach are relatively minor and will likely encounter soil and/or highly weathered bedrock to design depths. Proposed cut slopes of 1.5H:1V are expected to be stable. With many of the wetland fills, the existence of valley slopes will add to the overall global stability of the embankments through a buttressing effect, and 3H:1V or flatter embankment slopes should perform well.

The profile indicates an approximate maximum of 10 feet of fill at station 255+00. Because of the differing foundation materials beneath the partial cut - partial fill profile within this section, differential settlement is probable. Plans indicate construction with embankment foundation treatment from station 255+50 to 258+90. To facilitate construction and potentially reduce the effects of differential settlement, we recommend extending the placement of this foundation treatment eastward, beginning at approximate station 253+50. Similarly, we recommend embankment foundation treatment for the eastbound roadway and shoulder construction from approximate station 261+50 to 265+00.

Laboratory tests indicate the existence of moisture sensitive soils within this stretch. Significant increases in moisture content will be detrimental to the shear strength of these soils and could result in construction difficulties. The contractor should plan construction sequencing to minimize the volume of soil exposed to precipitation events, should anticipate stopping earth work during precipitation events, and should allow soils to adequately dry before attempting further earthwork. A Special Provision to address the handling of moisture sensitive soils is attached.

3.10: Station 267+50 to 300+50 (see logs 20 through 26). Borings #20, 21, 23, and 25 were located to evaluate subsurface conditions in proposed cuts, and all encountered bedrock within a few feet of the ground surface. Borings 22, 24, and 26 were drilled to evaluate subsurface materials for proposed embankments. The predominant soil types were silty sands (A-2), silts (A-4), and lean clays (A-6), and often contained rock fragments.

Soils within this section are firmer than those of the previous section, and should provide adequate foundation support for proposed embankments of up to 10 feet. Because much of the embankment profile is to be constructed over the existing alignment, settlement should be limited. Embankment slopes should be monitored closely during construction to ensure that the proposed maximum of 2H:1V is not exceeded.

The nature of the bedrock encountered here was again inconsistent. Fractures, degree of weathering, and hardness varied with location and depth. Seismic velocities from the traverse conducted adjacent to boring #20 were similar to those of other traverses. RQD, however, increased significantly with depth; a trend not observed in the samples from previous sections.

Cross-sections indicate proposed cut slopes as steep as ¼H:1V to the left of centerline, and a maximum cut depth of approximately 26 feet at station 283+00. Many of the cuts will involve bedrock excavation, and slopes of 1H:1V and flatter are recommended throughout most of this area. However, due to the highly-weathered nature of the bedrock, we advise only 1.5H:1V or flatter slopes from station 291+00 to 295+00.

As with many of the other cuts on this project, it is likely that much of material here will be excavatable with large equipment. However, increasing RQD numbers with depth suggest increasing bedrock competence, and blasting may be required for the deeper or more competent zones.

3.11: Station to 300+50 to End of Project (see logs 27 & 28). Soils encountered in borings near the eastern end of the project generally consisted of silty sands (A-1 and A-2), and lean clays (A-6). Many of the soil horizons contained rock fragments and varying amounts of gravel. Near-surface soils were loose or soft to medium-stiff, and high groundwater elevations were observed.

Both of the borings were located in the ditch to the right of the existing PTW, and therefore conditions may not be representative of subgrade conditions beneath the current alignment. Similar to the previous section, much of the embankment profile is to be constructed atop the existing alignment, and settlement will likely be more severe in the shoulder and ditch areas. Although differential settlement could be substantial, we anticipate that it should occur rapidly, allowing the contractor to correct any potential problems during construction. Proposed embankment slopes of 3H:1V and flatter are expected to be stable.

Cross-sections indicate cuts to the right of centerline and a maximum cut depth of approximately 14 feet at station 306+50. We anticipate that the majority of the cuts here will involve soil or weathered bedrock, and will not require blasting. Planned cut slopes of 1.5H:1V should be stable.

4.0: SHRINK/SWELL RECOMMENDATIONS

Based on an evaluation of the soil and rock samples collected, it appears that most of the material excavated from the cut area will be rock, although highly weathered in some cases. We recommend that a shrinkage factor of 10 to 15 percent be used for this material when used as embankment fill.

5.0: LIMITATIONS

Professional judgments and recommendations are presented in this report. They are based partly on evaluation of the technical information gathered, partly on historical information available, and partly on the Geotechnical Section's general experience with subsurface conditions in the area. The Geotechnical Section does not guarantee the performance of the project in any respect other than that the engineering work and the judgment rendered meet the standards and care of the profession. It should be noted that the borings may not represent potentially unfavorable subsurface conditions between borings. If, during construction, soil or rock conditions are encountered that vary from those discussed in this report or historical reports, or if alignment and grade and/or configurations change, the Geotechnical Section should be notified immediately in order that it may evaluate effects, if any, on our recommendations. The recommendations presented in this report are applicable only to this specific site. These data are not to be used for other purposes.

Original: Geotechnical Project File

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Geotechnical Correspondence File

Attachments: Boring Location Map, Boring Logs, and Boring Log Keys
Summary of Soil Index Test Results
Draft Controlled Blasting Special Provision
Moisture Sensitive Soils Special Provision
Embankment Foundation Treatment Special Provision
Form 111: Summary of Soil Survey Data